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(71) Applicant *(for all designated States except US)*: **THE UNIVERSITY OF SURREY** [GB/GB]; Guildford, Surrey GU2 7XH (GB).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **MORTON, Edward, James** [GB/GB]; 37 Banders Rise, Merrow, Guildford, Surrey GU1 2SL (GB).

(74) Agent: **BUTLER, Lance**; Barker Brettell, 10-12 Priests Bridge, London SW15 5JE (GB).

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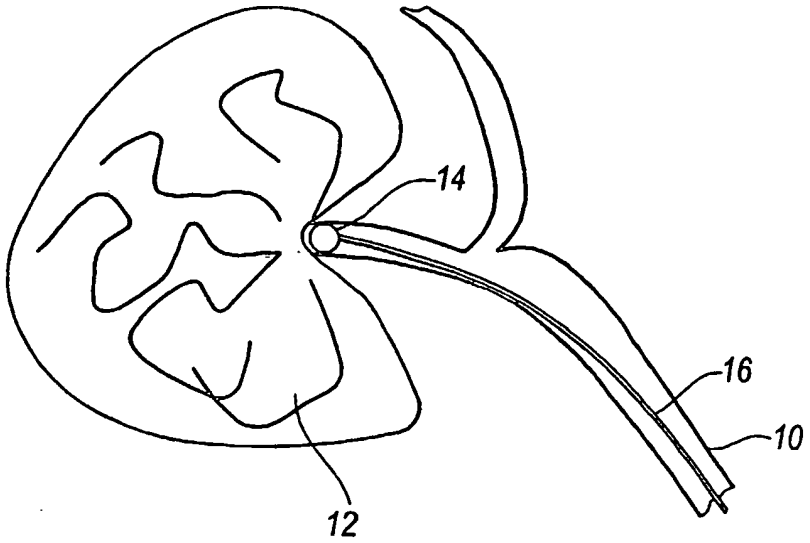
(54) Title: IMAGE COLOURING



(57) **Abstract:** In a method of fluoroscopic X-ray imaging employing an X-ray irradiation unit, image processor and an imaging chain including a display monitor, the key parameters of a displayed greyscale image are highlighted by the addition of colouring according to a predetermined colour coding pattern.

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Image Colouring

This invention relates to applying colour to an image. It is particularly concerned with the addition of colour to images employed in X-ray fluoroscopy.

X-ray fluoroscopy is a commonly used procedure for guiding interventional procedures within the body, or for visualising the structure/function of internal organs in the body. It is characterised by the use of X-ray imaging at video rate (normally 6 to 30 frames per second).

Conventionally, an X-ray imaging system for fluoroscopy comprises an X-ray irradiation unit (for example an X-ray tube and generator, collimator assembly, beam filter(s) and light beam diaphragm) combined with an imaging chain (for example, an X-ray image intensifier, lens system with optical iris, video camera, image processor and monitors). The images are observed by one or more specialist clinicians. The monitors have hitherto been greyscale units, giving an image which relies on clear contrast between the displayed features to permit the clinicians to assess the progress of the respective procedure.

Typical clinical applications of fluoroscopy include interventional neuroradiology, cardiology and peripheral vascular angiography. These are all techniques involving a high degree of risk of harm to a patient and thus require extremely careful control of instruments such as catheters to be inserted into the patient. In particular it is highly desirable that the X-ray images presented to clinicians operating the applications should be very clear in indicating the detail of the part of the body under investigation and in showing the precise location of inserted instruments.

A related problem is that prolonged exposure to X-ray irradiation poses in itself a health risk, especially to the patient undergoing treatment, but

also to the clinicians conducting the treatment. Although the dose received by the clinicians at an individual treatment may be relatively small, their repeated exposure in treatment of successive patients adds to a total level of irradiation which places an upper limit on the number of treatments they can conduct. It is therefore desirable that the period of exposure to irradiation should be kept as short as possible, which in turn requires that clinicians shall be quickly able to assess an image and the action they need to take in response to it.

During interventional procedures in which X-ray fluoroscopy or angiography is used to guide the clinician, important details such as the tip of a catheter may become obscured. This is particularly the case when the catheter passes up a vessel that lies parallel to the X-ray beam direction. A further example occurs when the catheter tip is obscured by the presence of a bolus of contrast agent as it passes from the catheter into the vessel. Since the clinician frequently wishes to identify the location of the catheter tip with respect to patient soft-tissue anatomy, such obscuring of the tip is most unhelpful. Indeed, this is an instant when in many cases a full knowledge of the catheter tip position relative to the patient anatomy is most critical.

Our co-pending patent application on image control, filed on even date with the present application, relates to the use of a combination of parameters derived from the image to calculate output signals to enhance control of the process. An important preferred feature of that application is the use of computer-based algorithms to enhance the image quality and thus control of the procedure in question.

The present invention can similarly benefit from the associated use of control algorithms. It is moreover possible to partition the algorithms to apply colour for use with parallel computing systems.

The present invention has the objective of improving the quality of image presented to clinicians so as to facilitate their rapid perception of the important features of a fluoroscopic image or image sequence.

According to the invention there is provided a method for fluoroscopic X-ray imaging employing an X-ray irradiation unit, image processor and an imaging chain including a display monitor, characterised in that key parameters of a displayed greyscale image are highlighted by the addition of colouring according to a predetermined colour coding pattern.

The invention is based on the high level of sensitivity of the human eye to colour. The use of colour as claimed herein for X-ray fluoroscopy to substantially aids clinicians' perception of information in image sequences. Their enhanced perception has the great advantage of permitting reduction of procedure times, therefore reducing the irradiation dose received by the patient.

Therefore, the first example of the use of colour is to colour the catheter tip with respect to the greyscale displayed X-ray image.

In a particularly advantageous embodiment of the present invention the position of a catheter tip in the displayed image is tracked using suitable algorithms. Thus even when the catheter tip is momentarily obscured from the camera, the image presented to the clinicians still gives a reasonably accurate indication of the tip's position.

A predetermined colour coding pattern for the highlighted features is of particular importance. It ensures that a clinician familiar with the coding pattern can instantly recognise a highlighted item, its position on the display, and thus in the body, and its rate and direction of movement across the screen and within the body. The preferred colours according to the invention are described below with reference to the respective items of equipment, procedure and anatomical details.

The highlighted parameters are preferably displayed as at least normal size. A larger than normal display can be employed for one or more of the parameters if the observer conditions require this.

In the preferred colour coding according to the invention the colour for the catheter tip is light green. Typically, the colour is applied in a regular shape (i.e. a disk) rather than an irregular shape (such as might be recorded in the actual image), again to aid clinician perception.

In a further example, the catheter may include orientation markers which are normally small attenuating beads placed along the catheter wire. In this case, the orientation markers are preferably coloured in alternate colours (cyan and yellow are most preferred) to aid a three-dimensional perception of catheter position.

In a further example, the path followed by the catheter tip may be displayed by a "tail" of variable persistence. Normally, such a tail would be displayed in a single colour (dark green is preferred), but variable shaded tails may be used to encode velocity information as well as position. In this case, the colour of the tail can vary from dark green (slow velocity) to bright green (high velocity). Alternatively a variable colour scale can be used such as a hot-wire scale (red-orange-yellow-white). Normally, the persistence of the tail is several seconds, although it can vary from zero to infinite duration. Markers at the end of the tail are preferably displayed at low intensity (almost transparent), while those at the head of the tail are high intensity (almost opaque). In a further option, the colour of all elements in the tail can be made the same, and they are merely removed from the end of the tail at the required persistence lifetime.

In a further embodiment of the invention, the catheter wire may be identified and coloured (e.g. in dark red) to allow the clinician to observe motion of the full catheter wire within the patient. This can help to

identify any coiling of the catheter before it becomes problematic, and can also aid clinician perception on how best to manipulate the catheter through the vessel.

In a further embodiment, colour can be used to indicate the relative movement of features. For example, a contrast agent flowing upwards can be coloured red while a contrast agent moving downwards can be coloured blue. This aids three-dimensional perception of the contrast flow and hence of patient anatomy.

In a further example, colour may be used to indicate the presence and/or velocity of contrast agent as it flows through vessels. For example, a binary segmented image of vessels containing contrast agent can be generated, and then the segmented regions (i.e. the blood vessels) coloured to indicate velocity of the contrast. Typically a rainbow spectrum (red-orange-yellow-green-blue-violet) can be used with the coloured image overlaying the greyscale anatomical image. In this case red represents high velocity and violet low velocity. Further, the intensity of the colour may be related to the remaining intensity of contrast in the vessel, such that the colour image fades as the contrast agent disperses. Alternatively, the coloured vessels may be maintained on the display, and the live catheter tracked through the coloured image. In this case, the catheter tip colour needs to be adjusted to contrast with the vessel colour.

Moreover the location and motion of the patient's anatomical features (e.g. regions of cardiac tissue) can be colour coded to aid clinician diagnosis. This is particularly important during slow motion playback of recorded image sequences to aid clinician diagnosis.

The applied colours to a greyscale anatomical image may be transparent or opaque.

A method for generating suitable colouring based on information extracted from the image itself is required. The preferred system for generating this information comprises an image computer that connects the image sensor to the image display. The image computer interprets the input image by calculating a set of low-level image parameters. Examples of the parameters include pixel-by-pixel motion vectors, pixel-by-pixel statistical properties such as significance of change in grey level and location of image features such as the catheter tip, orientation markers and guide wire. Based on the extracted data, high level parameters are determined such as global patient motion and the location and velocity of contrast agent.

Low level and high level parameters are then combined to determine suitable colouring for the displayed image. This is achieved by applying algorithms which use linear rule-based logic, fuzzy logic, neural networks and/or other linear or non-linear methods as appropriate.

Typically, the image computer comprises a parallel set of processors (e.g. digital signal processors or PCs) connected through a high speed digital backplane or via a high bandwidth network. Alternately, a custom processor may be designed, and construction techniques including high density three-dimensional interconnects and multi-chip modules may be employed. Often, programmable logic devices can be used to speed up otherwise compute intensive tasks such as binary segmentation of images.

There are several ways to segment the image data amongst the various processors. Typically, in a bespoke system containing embedded processors, complete images are copied to all processors simultaneously, and each processor determines the value of a single parameter or set of parameters. The results are fed back to further processors that implement the decision making algorithm and apply the colours into the output image frame buffer. In a commodity PC network (e.g. a beowolf PC cluster) it

is generally more efficient to send part of an image to each PC in the cluster, and perform all processing on that segment of the image within the same PC. Generally, multi-processor PCs are required, with one or more processors to extract the basic information, and one to generate the output image colours.

The present invention is further described with reference to the accompanying figure, which is a diagrammatic view of a celebral blood vessel with an interventional catheter in position.

The blood vessel, indicated by the reference numeral 10, has an associated aneurism 12 which the clinician seeks to address. A catheter which has been inserted into the vessel 10 has its tip identified by a circular marker disc 14. The catheter has within it a wire 16 with a coil memory. When the catheter tip 14 reaches the part of the aneurism 12 the clinician wishes to treat the wire 16 is pushed out of the end of the catheter and reverts within the vessel 10 to its coiled shape and provides an obstruction around which blood clotting can occur, thereby restricting the blood flow and relieving pressure on the aneurism 12.

Using the preferred colour coding of the invention the display image, which is otherwise greyscale, shows the catheter tip 10 as substantially opaque light green and the catheter wire as substantially opaque dark red. A tail showing the previous movement of the tip 10, which substantially follows the line of the wire 16 is opaque dark green at the tip end and transparent dark green remote from the tip.

Claims

1. A method for fluoroscopic X-ray imaging employing an X-ray irradiation unit, image processor and an imaging chain including a display monitor, characterised in that key parameters of a displayed greyscale image are highlighted by the addition of colouring according to a predetermined colour coding pattern.

2. A method as claimed in claim 1, in which the position of a catheter tip in the displayed image is highlighted in colour.

3. A method as claimed in claim 1 or claim 2, in which the position of a catheter tip in the displayed image is tracked using suitable algorithms.

4. A method as claimed in any preceding claim, in which the highlighted features are coloured according to predetermined colour coding pattern.

5. A method as claimed in any preceding claim, in which the highlighted parameters are preferably displayed as at least normal size.

6. A method as claimed in any preceding claim, in which the colour for the catheter tip is light green.

7. A method as claimed in any preceding claim, in which the colour is applied in a regular shape.

8. A method as claimed in any preceding claim, in which orientation markers are placed along a catheter wire.

9. A method as claimed in claim 8, in which the orientation markers are small attenuating beads.

10. A method as claimed in claim 8 or claim 9, in which the orientation markers are of alternate colours.

11. A method as claimed in claim 10, in which the alternate colours are cyan and yellow.

12. A method as claimed in any preceding claim, in which the path followed by a catheter tip may be displayed by a "tail" of variable persistence.

13. A method as claimed in claim 12, in which the tail is displayed in a single colour.

14. A method as claimed in claim 13, in which the tail colour is dark green.

15. A method as claimed in any preceding claim, in which the tail is displayed in a variable shade.

16. A method as claimed in claim 15, in which the tail colour varies from dark green to bright green.

17. A method as claimed in any of claims 12 to 16, in which the displayed persistence of the tail is several seconds.

18. A method as claimed in any of claims 12 to 17, in which markers at the end of the tail are displayed at low, almost transparent, intensity while those at the head of the tail are of high almost opaque intensity.

19. A method as claimed in any of claims 12 to 14, in which the colour of all elements in the tail is the same.

20. A method as claimed in any preceding claim, in which a catheter wire is identified and coloured.

21. A method as claimed in claim 20, in which the wire is coloured dark red.

22. A method as claimed in any preceding claim, in which colour is used to indicate the relative movement of features.

24. A method as claimed in any preceding claim, in which colour is used to indicate the presence and/or velocity of contrast agent.

25. A method as claimed in claim 24, in which a rainbow spectrum (red-orange-yellow-green-blue-violet) is used for the coloured image to overlay the greyscale anatomical image.

27. A method as claimed in claim 25, in which red represents high velocity flow and violet low velocity flow.

28. A method as claimed in any one of claims 24 to 27, in which the intensity of the colour is related to the remaining intensity of contrast in a blood vessel.

29. A method as claimed in any preceding claim, in which the location and motion of the patient's anatomical features are colour coded.

30. A method as claimed in any preceding claim, in which the colours to a greyscale anatomical image are transparent or opaque.

31. A method as claimed in any preceding claim, in which the colouring is generated from information extracted from the image itself.

32. A method as claimed in claim 31, in which the information comprises an image computer that connects an image sensor to the image display.

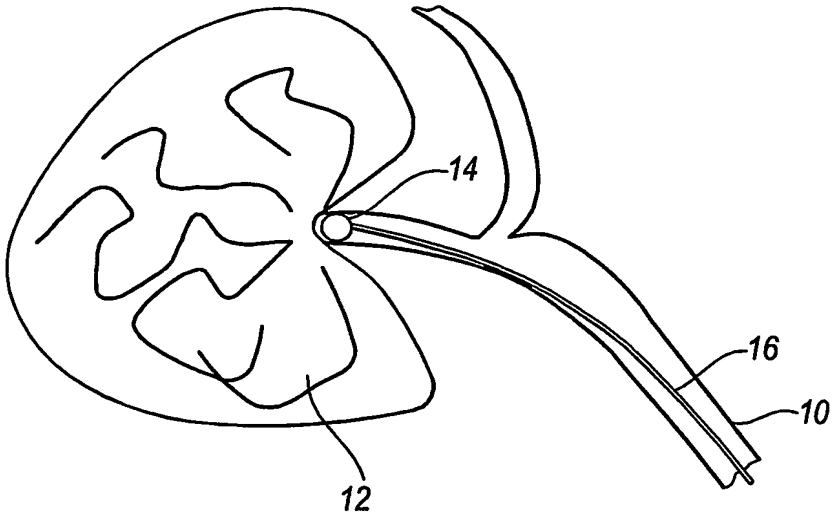
33. A method as claimed in any preceding claim, in which low level and high level parameters are combined to determine suitable colouring for the displayed image.

34. A method as claimed in any preceding claim, in which an image computer comprises a parallel set of processors (e.g. digital signal processors or PCs) connected through a high speed digital backplane or via a high bandwidth network.

35. A method as claimed in any one of claims 1 to 34, in which an image computer is a custom processor employing high density three-dimensional interconnects and multi-chip modules.

36. A method as claimed in any preceding claim, in which image data is segmented among image processors in a bespoke system in which complete images are copied to all processors simultaneously.

37. A method as claimed in any preceding claim, in which a separate processor determines the value of a single parameter or set of parameters and the results are fed back to further processors that implement a decision making algorithm to apply colours to the image.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INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B6/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC

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[X] Further documents are listed in the continuation of box C. [X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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